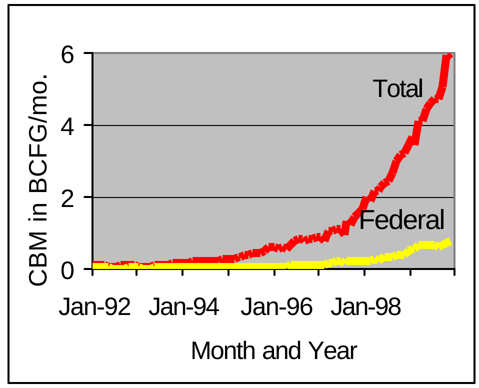
February 29, 2000

Interim Drainage Report on Coalbed Methane Development in T. 43-52 N., R. 70-75 W., Campbell County, Wyoming

Introduction

Coalbed methane (CBM) production from the Powder River Basin has increased 68 percent annually since 1994. In November 1999, 5.9 billion cubic feet (BCF) of CBM was produced in Wyoming, almost all of it from the Buffalo Field Office area. The comparison between federal and total CBM production is shown in the graph (data are from Wyoming Oil and Gas Conservation Commission). The number of producing CBM wells shows a similar trend. Although 54 percent of the Powder River Basin is federal minerals, only 14 percent of the CBM production, and 17 percent of the producing wells are federal. Between January 1, 2000 and February 3, 2000, 1089 applications to drill a CBM well were approved by the Wyoming Oil and Gas Conservation Commission.



Drainage of federal minerals by nonfederal CBM wells is a concern. Data presented by Barrett Resources Corporation and Western Gas Resources Inc. indicated reservoir pressure has decreased over several townships in the CBM development area. Modeling by Joe Meyer, BLM hydrologist, indicated that in an undrilled area 9 to 22 pounds per square inch (psi) of pressure drawdown will occur as much as 1.5 miles from the boundary of the producing well pod after 18 months of water production (see Attachment I). Discussions with CBM operators indicate that significant pressure drawdown may occur three miles or further from producing CBM wells.

CBM Desorption and Production

CBM is desorbed from coal when pressure on the coal is reduced. This is accomplished by pumping water from the coal thereby decreasing the hydrostatic pressure. Data from five BLM monitor wells suggest that, in eastern Campbell County, CBM desorption starts when pressure at the top of the coal is 40 to 80 percent of original reservoir pressure. One monitor well indicated CBM started desorbing at 92 percent of original reservoir pressure. Data from 11 BLM water monitor wells are shown in the table below. Wells which have started desorbing CBM are stippled.

Although water and gas production from individual wells vary greatly, CBM wells usually have three distinct stages. These can be termed dewatering, mid-life, and final stages of production. The dewatering stage is marked by increasing gas and steady or decreasing water production. During the mid-life stage water and gas production are steady or decline slightly. Also, the gas production rate reaches a maximum during this stage. During the final stage gas and water production decline, with gas production often declining sharply (sometimes over 50 percent annually). The water-gas ratio usually declines during the dewatering and mid-life stages, then increases during the final stage of production. By the time the final stage of production begins about one-half to two-thirds of the gas has been recovered from the well. Although time varies considerably, the first two stages average about one to two years each. If the pressure has been reduced before a well is drilled, the dewatering and mid-life stages may average only one year total. CBM wells have an average life of 7 to 11 years; however, pressure depletion before the well is drilled may reduce well life to only two or three years.

Location	Depth to top of Coal in ft.	Initial pres. at top of coal-psig	Pres. At start of desor.-psig	Percent of original Pressure	Remarks
44N-72W-14	716	194	NA	97%	Not desorbing, 188 psi.
45N-71W- 6	328	91	NA	93%	Not desorbing, 85 psi.
45N-75W-31	1,459	436	NA	100%	Not desorbing, 437 psi.
46N-71W- 6	310	66	53	80%	
46N-72W-36	459	108	51	47%	
46N-72W-25	420	161	NA	88%	Not desorbing, 141 psi.
46N-72W-16	750	176	162	92%	
47N-71W-19	334	38	29	77%	
47N-72W- 2	336	75	30	40%	
48N-72W-22	438	114	68	60%	Recorder down at start.
48N-77W-12	1,435	522	NA	100%	Not desorbing, 521 psi.

Drainage Evaluation

After discussions with the WRMG, Joe Meyer (2000) developed potentiometric surface maps for 1980 and 1998 based on data from 183 water monitor wells. Maps showing pressure drawdown and percent of original reservoir pressure were also constructed for the top of the “generic Wyodak” Coal. Details of how the maps were constructed are given in the attached report. Although not a detailed measure of local pressure, the maps are a good regional evaluation of the area based on available public data. The maps covered T. 43-52 N., R. 70-75 W. The pressure depletion maps indicate two areas show significant pressure depletion. Area I includes T. 45-49 N., R. 71-73 W. and Area II includes T. 50-52 N., R. 71-73 W. Pressure loss in Area I is large and extensive. Relative pressure loss in Area II is about the same as Area I but covers a much smaller area. Area I is a higher priority for drainage protection. Well control in Area I is good; however, control in Area II is limited to wells near the coal mines; therefore, the pressure drawdown maps are more tentative.

Based on data from the 11 wells listed in the above table, pressure depletion contour lines were drawn at 40, 80, and 92 percent of original reservoir pressure. Contour intervals of 40, 80, and 92 percent of original reservoir pressure were used because they approximately match the pressures at which CBM began desorbing in the BLM water monitor wells. Five of the six water monitor wells (see above table) started desorbing CBM between 40 and 80 percent of original reservoir pressure. One well began desorbing gas at 92 percent of original reservoir pressure. Pressure drawdown areas were then ranked A, B, C, and D, with area A having the greatest drawdown and highest priority for drainage protection wells (see Attachments II and III). The number of sections with each ranking are: A= 183 sections (34 percent), B= 159 sections (29 percent), C= 122 sections (23 percent), and D= 76 sections (14 percent).

Generalized data from Langmuir isotherms and data from the BLM water monitor wells listed in the above table, allowed generalized estimates of the relative amount of gas that may have been lost due to pressure depletion. It was assumed desorption starts at 92 percent of original reservoir pressure. Areas with 92 percent or more original reservoir pressure probably have lost little if any CBM due to drainage. Areas with 60 percent of original reservoir pressure remaining may have lost as much as about 30 percent of original gas in place. Areas with 40 percent of original reservoir pressure may have lost as much as about 50 percent of original gas in place. Below 40 percent of original reservoir pressure, CBM has almost certainly been lost and that loss may exceed 50 percent of the original gas in place. Sections ranked A and B have the greatest need for drainage protection. Unfortunately, some undrilled federal acreage may have been so severely depleted that an economic well is no longer feasible.

Conclusions

Two areas show significant pressure depletion. Area I is the higher priority. Over 50 percent of the original gas in place on some undrilled federal acreage may have been lost due to pressure depletion. This depletion will continue to worsen and cover a wider area as CBM development continues. Area II also appears to have significant pressure depletion, but the depleted area is much smaller than Area I.

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Attachment I

Analysis and Interpretation of Potentiometric-Surface Data
Wyodak Coal - Powder River Basin, Wyoming

Introduction:

Development of coal-bed methane(CBM) reserves in the Powder River Basin of Wyoming has been occurring at an ever increasing rate since 1993. Development of federal methane reserves has not kept pace with development of fee and state methane reserves due to permitting restrictions. In November of 1998 several CBM producers approached the Bureau of Land Management (BLM) with concerns that federal methane reserves were being drained by development of adjacent non-federal methane leases. The Wyoming Bureau Of Land Management (BLM) Reservoir Management Group (RMG) is tasked with determining the validity of drainage cases on federal methane leases. In order to make this determination the RMG requested the Casper Field Office (CFO) soil scientist / hydrologist to provide an analysis of historic and current water level data for the Wyodak coal.

Data analysis requested by RMG included:

Historic (pre-CBM) water level data.
Historic (pre-CBM) water pressure above the top of the Wyodak coal.
Current water level data.
Current water pressure above the top of the Wyodak coal.
Projected areal impacts of producing methane well(s).

Water Level Data:

Water level data for the Wyodak coal is available from several sources. The most extensive single set of data has been compiled by the Gillette Area Groundwater Monitoring Organization (GAGMO). Water level data from GAGMO has been collected and published annually since 1980.

A second widely accepted source of pre-CBM water level data is available in "Potentiometric-Surface Map Of The Wyodak-Anderson Coal Bed, Powder River Structural Basin, Wyoming, 1973-84" (Daddow, 1986, U.S.G.S. WRIR Report 85-4305).

In addition, recent groundwater modeling efforts conducted for the "Wyodak Coal Bed Methane Project - Environmental Impact Statement"(BLM, Oct. 1999) and included in the technical report titled "Groundwater Modeling Of Impacts Associated With Mining And Coal Bed Methane Development In The Eastern Powder River Basin" provides both historical and current projected regional water levels.

Groundwater monitoring wells operated by the CFO - BLM were also available to give both historic and current water level trends relating to CBM development.

The Wyoming State Engineers Office (WSEO) operates six monitoring wells to track water level draw-downs as a result of CBM production. Most of the data available from WSEO monitoring wells starts in December of 1998.

Two CBM producers provided BLM with draw-down and potentiometric-surface maps and data water level data collected at producing well fields. This data was also considered as part of the analysis.

Coal Structure Data:

The most extensive data available relating to the structure of the Wyodak coal is "National Coal Resource Assessment Non-Proprietary Data: Location, Stratigraphy, and Coal Quality of Selected Tertiary Coals in the Northern Rocky Mountains and Great Plains Region" (USGS, 1999, Open File Report 99-376).

Coal structure data was also obtained from the GAGMO database, BLM monitoring wells and data provided by two CBM operators.

Assumptions:

For the purpose of a "regional" drainage assessment it was assumed that the Wyodak coal is a "regionally" extensive aquifer, and water movement can occur across the entire basin.

The Wyodak coal can be defined by a single thickness seam of "regional" extent.

Methodology:

Potentiometric-surface maps were developed for 1980 and 1998. These maps were produced by compiling data from 183 monitoring wells. The data was contoured using "Surfer", a commercial contouring package, and plotted on a map base for analysis. The completed potentiometric-surface maps were compared to published sources (Daddow, GAGMO) to test the validity of the contouring routine.

To develop a generic Wyodak coal surface the USGS Coal Resource data was interpreted to define the first coal seam at a depth greater than 250 feet and a coal thickness greater than 30 feet. A general interpretation of this type was required due to the great variability in the occurrence of coal seams over the basin. Known coal tops from GAGMO, BLM and CBM wells were also used.

Formation pressure over the top of the Wyodak coal was computed by subtracting the elevation of the generic Wyodak coal surface from the potentiometric-surface maps prepared for each year, and converting the feet of water to pressure (psi).

Visual MODFLOW, a numerical groundwater modeling program was used to quantify the areal extent of draw-downs from CBM well pods. A uniform theoretical coal seam model was developed to test various scenarios. Model runs were conducted using various well densities, pumping rates and aquifer characteristics.

Data Limitations:

Water level data available for the Wyodak coal is concentrated near the outcrop. GAGMO was created to monitor the effects of surface coal mining, with most of the wells located within a few miles of the mines.

Data collected by BLM is more areally extensive, with wells located near many of the large producing methane fields. However, the total number of monitoring wells is small, and will not accurately reflect conditions more than several miles from each site.

WSEO data starts in December 1998. It was necessary to estimate starting (1980) year water levels for several of the wells. In addition, the draw-down values used from these wells represent December 1999 data. It was assumed that the 1999 data more accurately reflects the draw-down conditions occurring near these wells. By using the 1999 data from these wells, estimated draw-downs shown on the 1998 pressure loss maps may reflect a "worse case" scenario for 1998.

Water level data provided by the CBM operators is mostly reflective of pumping levels in the fields, and may not reflect the available formation pressure a short distance away from the well.

Interpretation and contouring of water level data from monitoring wells is a substantial simplification of actual conditions. Water levels can vary significantly over short distances as a result of changes in geologic conditions (faults, splits, parts, lineaments). Since the total number of monitoring wells available away from the outcrop is very small, the regional potentiometric-surface at any given point may not accurately reflect specific field conditions.

The "generic Wyodak" structure map developed to calculate formation pressures is very general. Since it is known that the coal contains many parts, splits, faults and lineaments, a generic simplification of the coal to a single continuous seam will produce errors in calculated pressures.

Analysis:

Analysis of results is based on two separate data sets. The first product was derived from comparison of potentiometric surfaces and the top of the "Wyodak" coal to calculate hydrostatic pressure over the top of the coal. Results of this exercise indicate substantial pressure loss over much of townships 45-71, 45-72, 46-71, 46-72, 47-71, 47-72, 48-71 and 48-72 between 1980 and 1998. In localized areas near pods of development pressure losses can be as high as 90 psi, with large areas experiencing pressure drops of 30 to 50 psi.

Interpretation of this data outside the above mentioned townships is greatly limited do to the large distance between control points. Well pods which are not within several miles of a monitoring well will not be accounted for in the pressure draw-down map.

A second analysis was completed using the output from a number of MODFLOW simulations to estimate the potential extent of draw-down produced by a one square mile development using spacing of 40 or 80 acres.

Results of the MODFLOW simulations indicate that 20 to 50 feet of draw-down will be produced up to 1.5 miles from the boundary of a producing well pod after 18 months of operation. In areas where monitoring wells are widely spaced, it will be necessary to interpolate projected draw-downs from the project boundary using the results of the MODFLOW simulations as guidance.

Summary:

Pressure drops calculated from potentiometric surface maps are general in nature, but provide a broad regional picture of pressure loss in areas where monitoring well density approaches one to two monitoring wells per township. In areas without sufficient monitoring well density, pressure loss may be approximated using projections of draw-down produced using MODFLOW.

Great care must be used in the interpretation of this data at less than a “regional” scale since variations in coal aquifer characteristics such as faults, lineaments and splits will influence water levels over short distances.

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February 28, 2000

Attachment III

Interim Drainage Map